Evaluation of the Impact of Heat Stress on Dry Cows and Subsequent Performance and Health

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Take-Home Message

Substantial evidence is now available to support actively cooling dry cows for the entire dry period. Relative to heat stress, cooling during late gestation increases mammary growth, maintains dry matter intake, and improves immune status during the transition into lactation. When compared with herdmates that calved in months of significant heat stress, dry cows calving in cooler seasons have greater milk yield, improved reproductive performance and fewer disease incidents. Cooling dry cows is an easily implemented management intervention that should lead to improved animal well-being, production and health, and in turn higher financial returns to the dairy.

Introduction

Lactating dairy cattle produce significant amounts of heat during fermentative digestion, and it is no wonder that they are efficient at dissipating that heat load under normal environmental conditions. But heat stress develops at temperatures as low as 72 °F, so cows can suffer negative outcomes during much of the year in the US, even in northern states (Collier et al., 2006). During heat stress lactating cows will experience a decline in milk yield due partially to decreased dry matter intake and also to physiological adaptations to rid the body of excess heat (Wheelock et al. 2010).

In contrast to lactating cows, the lower dry matter intake and metabolic heat load of dry cows improves their ability to successfully adapt to heat stress. However, heat stress does negatively impact dry cows and a limited number of studies have shown benefits to management interventions such as passive (i.e. shade) and active (i.e. fans and soakers) cooling to alleviate that heat stress (Collier et al., 1982; Wolfenson et al., 1988). Despite numerous attempts to identify the biological basis of the negative effects of heat stress, events at the cellular and tissue level remained unknown and served as a stimulus to the investigations described below. Additional details regarding the impact of heat stress on dry cows and their calves were recently reviewed in Tao and Dahl, 2013.

Heat Stress Impacts on Mammary Function and Metabolism

We have used the same experimental design for a series of studies to investigate the effects of actively cooling dry cows on their subsequent performance and health. In that system, cows are dried off approximately 6 weeks before their expected due date, and housed in an open sided, sand bedded free stall barn. Within a pen, cows that are cooled (CL) will have feed-line soakers and fans, whereas cows that will experience heat stress do not have soakers or fans, only shade. The studies have been conducted between May and October in Florida, when average daily temperatures exceed 85 °F and maximum daily relative humidity is above 90%. All other management is the same for both groups during the dry period. Following calving, all cows are housed and managed as a group and cooled according to standard farm protocols. Using this approach we have isolated the effects of dry period heat stress on various aspects of production and health.

Our first objective was to determine if, and to what extent, heat stress in the dry period adversely affected milk yield at the level of the mammary gland. Consistent with previous studies we observed a decrease in milk yield following dry period heat stress, such that CL cows produce 5 to 7 pounds more milk each day compared with the HT cows (Summarized in Figure 1). This yield differential is apparent from very early in lactation and persists for at least 40 weeks (Figure 2; Tao et al., 2011). That observation indicates that the mammary gland is programmed to produce more milk for the entire lactation when heat stress is avoided during late gestation. A sequential series of mammary biopsies revealed that mammary cell proliferation was greater in cooled dry cows relative to those that were heat stressed (Tao et al., 2011). Therefore, the depression in yield in HT cows results from a reduction in mammary growth during the dry period, and the cows enter lactation with a lower capacity to produce milk relative to CL animals.

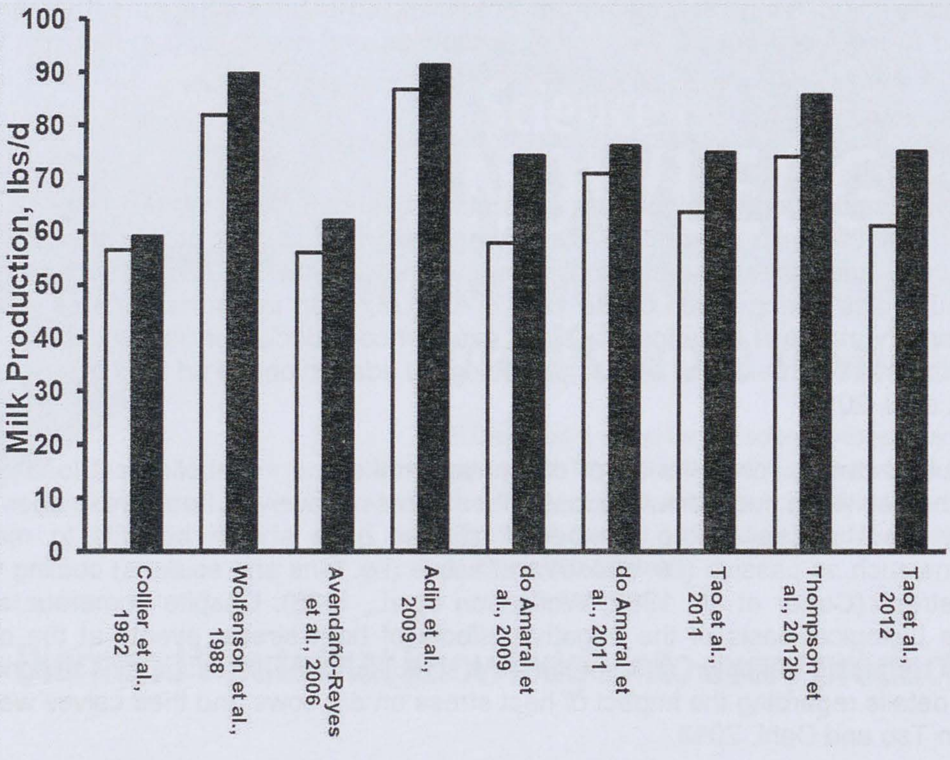

Figure 1. Summary of milk yield response to dry period cooling in 9 studies. Details of experimental design and other performance measures can be found in individual references. Redrawn from Tao et al., 2013. Open and solid bars represent the dairy subsequent milk production (lbs/d) of dry period heat stressed and cooled cows, respectively.

Regardless of the impact of heat stress on the mammary gland, without coordination of responses in tissues that support energy partitioning in support of milk production the cow will not increase yield. When cows are heat stressed in the dry period they will reduce their dry matter intake relative to those cooled, and there is a concomitant reduction in bodyweight gain and body condition score in heat stressed dry cows (do Amaral et al., 2009; Tao et al. 2012b).

Examination of liver function via expression of genes involved in lipid mobilization and trafficking during the dry period and early lactation indicates that cooling during the dry period improves hepatic lipid metabolism such that greater yields can be supported relative to cows that are heat stressed, even when all cows are cooled during lactation (do Amaral et al., 2009).

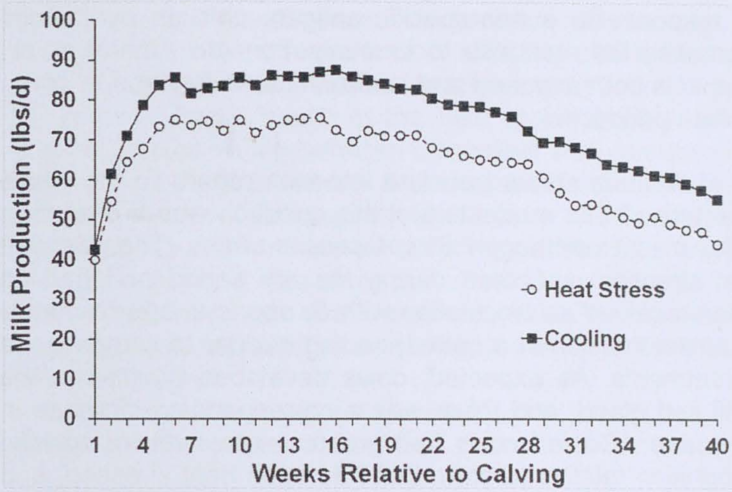

Figure 2. Milk yield of cows exposed to heat stress or cooling during the dry period. Dry period cooling increased yield relative to heat stress. Cows were managed identically, including cooling, during lactation. Redrawn from Tao et al., 2011.

Further studies were completed to characterize shifts in energy metabolism when cows were cooled in the dry period. Our experimental approach was to conduct a series of glucose and insulin challenges in cows that were heat stressed or cooled when dry, during both the dry period and lactation (Tao et al., 2012). Despite substantial reductions in dry matter intake of heat stressed dry cows compared with cooled cows, there are no differences in mean concentrations of insulin or circulating glucose, nor were any differences observed between groups to the glucose or insulin challenges during the dry period. These data suggest that in contrast to lactating cows (Wheelock et al., 2010), heat stress does not alter carbohydrate metabolism to any appreciable extent when dry. Of interest, the cows cooled when dry did have significantly greater responses to glucose and insulin once lactation began, but this is consistent with the substantial increase in milk yield and thus energetic demand in cows previously cooled relative to those that had been heat stressed.

Immune Function With Heat Stress

A particular issue with transition cows is an increase in disease incidence and generally reduced immune status, such that cows are most likely to experience a disease incident between dry off and the first 6 weeks in milk relative to any other time in the lactation cycle. Because of this, it is important to consider the impact of any management intervention on not only yield, but immune status as well, to ensure that cows are not at greater risk to develop disease.

The initial approach to examine immune status in transition cows that were heat stressed or cooled during the dry period were measures in blood samples collected during the dry period and early lactation, and on the responses of white blood cells from those samples under culture conditions. The white blood cells of cooled cows had greater capacity to proliferate relative to those from heat stressed cows, an indicator of stronger immune responsiveness (do Amaral et al., 2010). In addition, cows that are cooled exhibit improvements in expression patterns of a number of genes involved in leukocyte function, particularly those associated with adaptive immune responses (do Amaral et al., 2010).

While gene expression is of interest, it is important to understand if that pattern results in improved capacity of the white blood cells to attack and eliminate pathogens. Cooled cow neutrophils had higher oxidative burst activity and phagocytosis in early lactation relative to the cows that were heat stressed when dry (do Amaral et al., 2011). This is evidence that cooling has carryover effects on immune status after calving. During the dry period, those cows that were being cooled had greater IgG response to a non-specific antigen, chicken ovalbumin, which indicates that heat stress decreases the response to immunization (do Amaral et al., 2011). Thus, heat stress negatively impacts both acquired and innate immune function in cows, although at different times in the transition period.

But what do these in vitro indicators of immune status translate into with regard to the whole cow, especially in the transition into lactation? Our model to test this question was a challenge directly at the mammary gland with the mastitis pathogen *Streptococcus uberis* (Thompson et al., 2012). Cows that had been heat stressed or cooled during the dry period and had no evidence of any intramammary infection received an inoculation with *S. uberis* at approximately 5 days in milk. Each cow received a saline infusion in a corresponding quarter to compare the effects within a cow and between treatments. As expected, cows developed mastitis in the inoculated gland versus the saline infused gland, and there was a corresponding increase in somatic cell count in the inoculated quarter. Cooled cows had greater expression of specific genes involved in early pathogen recognition relative to cows that had been heat stressed, and cooled cows also had higher white blood cell counts and total neutrophil numbers compared with heat stressed cows. Therefore, it appears that the in vitro indicators of improved immune status observed in cooled dry cow translate to a more robust immune response as they enter lactation. Further, that immune response is layered over greater milk yield, which is commonly associated with a more immune-compromised state.

Seasonal Effects on Dry Cows

Although seasonal impacts on milk yield have been recognized for some time, the prevailing view was that the effects were subsequent to calving and related to the acute heat stress that the animals exposure during lactation. We recently reviewed records of over 2,600 multiparous cows that calved during a 3-year period on the same commercial farm in Florida (Thompson and Dahl, 2012). The cows were separated by month of calving into two groups; 1) COOL (calved in December, January or February) and 2) HOT (calved in June, July and August) and a number of performance outcomes were assessed during the subsequent lactation. It is important to emphasize that the management conditions, including feed, milking and reproductive protocols, and housing, were similar at the farm throughout the study period, so interpretations related to season of calving are appropriate and relevant to field conditions.

COOL cows produced 1,215 lbs. more milk than the HOT cows, even though COOL cows spent more time producing milk in the hottest months of the year. There were differences between the groups in the organisms responsible for mastitis, but COOL cows had fewer cases of mastitis overall during the initial 80 DIM. In addition, the COOL cows had fewer cases of retained placenta and general respiratory problems that the HOT group, suggesting a more robust immune response in cows that are dry during cool months of the year. COOL cows though had more digestive problems that HOT cows, but that did not negatively impact their ability to produce milk as indicated above.

Of particular interest was the improved reproductive performance of COOL cows relative to those that were HOT. Despite higher milk yield and being bred during hotter summer months, COOL cows had fewer days to breeding, fewer days to pregnancy and they had fewer breedings overall compared with HOT cows. Again, the reproductive performance of these multiparous cows that were dry during the cooler months of the year refutes the dogma that higher milk yields and summer heat stress are necessarily antagonistic to strong reproductive management outcomes.

Whereas many environmental factors are affected by season, temperature, humidity and photoperiod are the primary factors affecting cow performance (Collier et al., 2006; Dahl et al., 2012). Indeed, previous studies clearly support a role of light exposure during the dry period on milk yield and cow health in the next lactation (Dahl et al., 2012). But the average daylight length in Florida during between December and January is 10.5 to 11.5 hours, much longer than the 8 hrs of light exposure that improves milk yield when imposed during the dry period. Moreover, the daylight length between June and August is only 13 to 14 hrs, much shorter than the 16 hrs used to improve yield during lactation. In contrast, using temperature-humidity index (THI) as a guide, it was clear that cows that calved in COOL months (mean THI = 54.8 ± 1.0) experienced less heat strain when dry than those calving in HOT months (THI = 76.2 ± 0.4). Thus, the seasonal effects on performance were likely due to the impact of heat stress rather than photoperiod.

Implementation

With regard to implementing heat stress management in the dry period, approaches are the same as those used with lactating cows. Whenever possible, cows should have access to active cooling to reduce the heat load during the hottest periods of the year. This means that shade, and if possible soakers or other cooling methods should be provided to dry cows even if they are in a pasture or dry lot. One approach is to have shade in a pasture or lot and active cooling at feed bunks within that pasture.

As important as the cooling arrangement is the duration of cooling that the cow experiences. For example, can cows be cooled only during the close up period and experience the positive outcomes on production and health described above? Although no direct comparison has been made, based on results from various studies it appears that cooling for the entire dry period yields the greatest response. In our series of studies over a 6 year period we observed a 5 to 7 pound per day improvement in milk yield in the next lactation with active cooling initiated at dry off and maintained for a typical 6 week dry period. In contrast, Urdaz et al. (2006) found that cooling cows for the final 3 weeks of a 60-day dry period resulted in an increase of 1 to 2 pounds of milk in the subsequent lactation. Thus, comparison of those studies suggests that a more robust improvement in yield and other desirable outcomes is associated with cooling for the entire dry period.

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